

Figure 28



Figure 29



Figure 30



Figure 31



Figure 32



Figure 33



Figure 34

APPENDIX

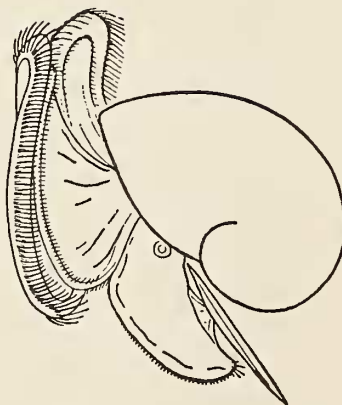
USNM No.	Formation	Description
701-l	Wolfcamp (bed 2)	About 1410m elevation on south side of hill, 1.392 km south 69° west of Hill 5060, Wolfcamp Hills, Hess Canyon quadrangle, Texas
702	Leonard, upper part (original Leonard of P. B. King)	Slopes on south side of road, 320 to 800m east of Split Tank, 2.4 km northeast of road fork near old Word Ranch, about 30 km NNE of Marathon, Hess Canyon quadrangle, Texas
703	Word (ls. no. 1)	Lens with goniatites in platy limestone near top of slope 800m SW of road forks just NE of old Word Ranch, Hess Canyon quadrangle, Texas
703-a	Uppermost Leonard (<i>Aulosteges</i> bed)	On NW side of road between road fork and sheep tank, 320m N 10° E of Old Word Ranch, Hess Canyon quadrangle, Texas
703-bs	Base of Cathedral Mtn.	Smooth, light grey ls. containing <i>Stratifera</i> -like shells just on rocks of Hess lithology about 272m S 39° W of old Word Ranch, Hess Canyon quadrangle, Texas
703-c	Word (ls. no. 1)	Crest of slope 400m to 800m SW of road fork near old Word Ranch, 27 to 29 km NNE of Marathon, Hess Canyon quadrangle, Texas. Sponge bed. Basal portion, dark platy, is called Word no. 1 by P. B. King, just above reefy beds on crest of slope on N-side of road
706-b	Word	Ls. between ls. no. 3 and ls. no. 4, 320m W of junction of Hess Canyon with S branch of Hess Canyon, Hess Canyon quadrangle, Texas
706-c	Word	About middle of ls. no. 2, SW slope and crest of low hill 5.92 km N 36° E (air-line) of Hess ranch house, Hess Canyon quadrangle, Texas
707-d	Wolfcamp (top)	Knob on W side of entrance to Sullivan Ranch Canyon, 5.6 km N 7° E of Decie ranch house, Altuda quadrangle, Texas
707-e	Wolfcamp (lower)	8.48 km (airline) N 5° W of Decie ranch house, 1.44 km (airline) S 25° E of Sullivan Peak, on nose of foothill SE of Sullivan Peak, Altuda quadrangle, Texas
707-ha	Skinner Ranch	Poplar tank member (<i>Productid</i> bed), above beaded <i>Leptotid</i> , loose on small knob, 800m SE of Hill 5300, 4.32 km (airline) N 12° W of Decie Ranch house, Altuda quadrangle, Texas
709-c	Road Canyon (Word)	Ls. with <i>Coscinophora</i> , on W slope hill, 1.52 km N 9° E of Hill 4920, Altuda quadrangle, Texas. Also 1.8 km S, 57° E of Sullivan Peak (BM 6125)
719-x	Road Canyon	2.272 km N, 19° W of Hess ranch house, 880m N 65° E of Hill 5453, Hess Canyon quadrangle, Texas
720-d	Road Canyon (top)	Lens 7.5m above ls. mapped as Lower Word, 1.856 km S 31° E of BM 4973, Gilliland Canyon, Altuda quadrangle, Texas
720-g	Skinner Ranch	Decie Ranch Member (<i>Scacchinella</i> beds), at break in slope 2.16 km S 83° W of Hill 5816, NW side Hess Ranch, Hess Canyon quadrangle, Texas
721-j	Road Canyon	2.32 km N 19° W of Hess Ranch House, Hess Canyon quadrangle, Texas
721-s	Road Canyon	2.768 km N 1½° W of Hess Ranch House, Hess Canyon quadrangle, Texas
721-t	Road Canyon	2.88 km N 10½° W of Hess Ranch house, Hess Canyon quadrangle, Texas
721-u	Cathedral Mountain	912 m N 80° E of Hill 4910, Altuda quadrangle, Texas, approximately loc. 120 of R. E. King
721-y	Road Canyon	1.92 km S 25° E of BM 4973, Gilliland Canyon, Altuda quadrangle, Texas
721-z	Road Canyon	1.52 km S 28° E of BM 4973 Gilliland Canyon, Altuda quadrangle, Texas
722-g	Road Canyon	2.32 km S 72° W of Hill 4910, 2 km N 9° E of Hill 4920, Altuda quadrangle, Texas
722-l	Skinner Ranch	Sullivan Peak Member, 2.768 km S 1½° E of old Payne Ranch, W flank of Dugout Mtn., Monument Spring quadrangle, Texas
725-c	Bone Spring	39m above Hueco ls., E side of Hill 4402, N end of Baylor Mts., W side Texas Hwy. 54, 960m S 22½° W of BM 3806, Van Horn (30') quadrangle, Texas
725-d	Bone Spring	Same as 725-c, but 32.4m above Hueco ls.
726-d	Road Canyon	Small " <i>Leptodus</i> " bed, at 1484m elevation, 2.192 km S 4° W of Willis Ranch, 1.568 km N 68° E of Hill 5801, Hess Canyon quadrangle, Texas
726-o	Cathedral Mountain	1.728 km S 2° E of Hill 5507, 1.648 km S 76° W of old Word Ranch, Hess Canyon quadrangle, Texas
726-r	Word	Ls. no. 2, China Tank Member, 2.288 km N 70° W of old Word Ranch, Hess Canyon quadrangle, Texas
726-z	Road Canyon (lower)	1.648 km N 43° E of old Word Ranch, 848m S 20° E of Hill 5461, Hess Canyon quadrangle, Texas
727-a	Skinner Ranch (Sullivan Peak)	2.608 km S 50° E of old Payne Ranch, 592m N 31° W of Hill 5195, Dugout Mtn., Monument Spring quadrangle, Texas
728	Cherry Canyon	Getaway ls. Member, near break in the slope on middle leader on the W side of the airway station road, between the highway and the pipeline road, on the crest of the ridge, Guadalupe Mtns., Texas
731	Bell Canyon	Hegler Member, top of Hill 5130, 800m SSW of Pinyon Tank, S of Getaway Gap, Guadalupe Peak quadrangle, Texas
735-a	Road Canyon	Lower Word ls, old Word Ranch, Hess Canyon quadrangle, Texas

The appendix on the preceding page is a

Register of West Texas Permian Chiton Localities

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Morphological Correlations Between Dorid Nudibranch Predators and Sponge Prey

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(1 Text figure)

INTRODUCTION

MORPHOLOGICAL AND BEHAVIORAL specializations of a predator to its prey have been noted for birds (EDINGTON & EDINGTON, 1972; LACK, 1947; PERKINS, 1903), reptiles (PIANKA, 1969), fish (EMERY, 1973; FRYER, 1959; JONES, 1968; KEAST & WEBB, 1966), grasshoppers (ISELY, 1944) and opisthobranchs (EVANS, 1953; GRAHAM, 1938; HURST, 1965; LALLI, 1970; YOUNG, 1969). These specializations have been inferred to have arisen due to competition (BROWN & WILSON, 1956; CODY, 1968; DARLINGTON, 1972; HUTCHINSON, 1966) or due to selection to minimize utilization costs on patchy, divergent prey (BLOOM, 1974).

While feeding and digestive morphologies of sponge-rasping dorid nudibranchs (*sensu* YOUNG, 1969) are well known (see Discussion below for references), and skeletal morphologies of the sponge prey are available in the taxonomic literature, little attention has been paid to correlations of predator-to-prey morphologies within the sponge-rasping dorid nudibranch category.

By critically examining dorid nudibranch and sponge morphologies with regard to predatory correlations, certain logical predictions of prey-preferences by the predators result. The prediction that dorids with certain character-sets should preferentially consume sponges with certain skeletal organizations can be tested with laboratory preference studies and observations of diets of dorids in nature. Partial literature reviews exist (FOURNIER, 1969; MILLER, 1961; THOMPSON, 1964), although many of the reported observations do not fulfill the criteria listed by SWENNEN (1961) that the animal be found on or near the food, that the animal be observed to ingest the food, and that the animal be known to subsist on the food. The combination of these 3 reviews, recent work by many authors and my own observations provides an adequate data-basis to test the hypothesis that a correlation between dorid and sponge morphologies exists.

METHODS AND MATERIALS

Specimens of *Archidoris montereyensis* (Cooper, 1862), *A. odhneri* (MacFarland, 1966), *Cadlina luteomarginata* MacFarland, 1905, *Diaulula sandiegensis* (Cooper, 1862), *Anisodoris nobilis* (MacFarland, 1905) and *Discodoris heathi* MacFarland, 1905 were collected from several intertidal and many subtidal stations (by SCUBA diving) near San Juan Island, Puget Sound, Washington between March 1970 and December 1973. The estimated wet weight of each nudibranch, its species and the location and depth of the station were recorded. Over 600 individual nudibranchs were collected for study. The dorids were placed in thoroughly cleaned one liter capacity plastic containers with screened sides in clean shallow aquaria with flowing, filtered seawater at the Friday Harbor Marine Laboratories, Friday Harbor, Washington.

In order to identify prey species, feces were collected and processed according to the procedure outlined in LIGHT *et al.* (1954) and were examined to determine the spicule types present and thus the species of sponge consumed. Identifications were made according to BAKUS (1966) and DE LAUBENFELS (1932, 1961). Dr. Bakus kindly verified the identifications of all species of sponge.

The shape of the radula teeth for those dorids known to eat sponge and for which radular teeth drawings or specimens were available was quantified. Radulae of the dorid species mentioned above were removed from the animals, cleaned in dilute NaOCl, dehydrated in 70 and 100% ethanol and mounted in Canada balsam. Before placement of the coverslip, teeth from the functional area of the radula (anterior one-third of the rows, middle one-third of a pair of rows) were pulled free. Teeth were then drawn, using a camera lucida, at 100 \times .

Tooth shape, or the degree of "hook" of the teeth was defined as the amount of concavity of the inner margin of the tooth. The method for measuring the concavity is shown in Figure 1. Curvature was averaged over 3 teeth

Table 1
Sponge species reported in dorid nudibranch diets.

	Skeletal description	Skeleton described by
HEXACTINELLIDA		
ROSSELLIDAE		
<i>Rossella racovitzae</i> Topsent	moderately hard; crumbly; long spicules	(Burton, 1929; Dayton, per. comm.)
<i>Rossella nuda</i> Topsent	harder than <i>R. racovitzae</i> ; long spicules	(Burton, 1929; Dayton, per comm.)
<i>Scolymastra joubini</i>		1
CALCAREA		
Calcinea		
LEUCETTIDAE		
LEUCASIDAE		
<i>Leucetta barbata</i> (Duchassing & Michelotti) ²	confused mass of triaxons; resembles Demospongiae	(de Laubenfels, 1950)
DEMOSPONGIAE		
Tetractinomorpha		
HOMOSCLEROPHORIDA		
PLAKINDAE		
<i>Plakortis simplex</i> Schulze	confused mass of spicules	(de Laubenfels, 1950; 1954)
CHORISTIDA		
STELLETTIDAE		
<i>Stelletta estrella</i> de Laubenfels	cartilaginous with radiate tracts	(de Laubenfels, 1932)
HADROMERIDA		
CLIONIDAE		
<i>Cliona celata</i> Grant	confused mass of spicules	(Bergquist, 1965a; de Laubenfels, 1961)
SUBERITIDAE		
<i>Stylotella columella</i>	confused mass of spicules	(de Laubenfels, 1954) ¹
<i>Suberites ficus</i> (Johnston)	confused mass of spicules	(de Laubenfels, 1932; Wells, 1960)
<i>Terpios aploos</i> de Laubenfels	confused mass to vague reticulation	(de Laubenfels, 1954)
<i>Terpios</i> sp.		1
<i>Terpios zeteki</i> de Laubenfels	confused mass of spicules	(Hechtel, 1965; de Laubenfels, 1950)
EPIPOLASIDA		
FETHYIDAE		
<i>Fethya aurantia</i> (Pallas)	radiate tracts without reticulation	(Bergquist, 1965a; de Laubenfels, 1932)
Ceractinomorpha		
HALICHONDRIIDA		
HALICHONDRIIDAE		
<i>Halichondria dura</i> Lingren	confused mass of spicules	(de Laubenfels, 1951)
<i>Halichondria panicea</i> (Pallas)	confused mass of spicules; crumb-of-bread	(de Laubenfels, 1932)
<i>Halichondria</i> sp.		1
HYMENACIDONIDAE		
<i>Hymeniacidon perleve</i> (Montagu) ³	confused mass of spicules	(Bergquist, 1970)
<i>Hymeniacidon</i> sp.		1
<i>Prunus phlox</i> de Laubenfels	confused mass of spicules	(de Laubenfels, 1954)
<i>Prunus</i> sp.		1
HIGGINSIDAE		
<i>Higginsia</i> sp.	confused mass to vague reticulation	(Higgins, 1877) ¹
HAPLOSCLERIDA		
DESMACIDONIDAE		
<i>Desmacidon</i> sp.	assumed to resemble other in order	(Bergquist, 1965b) ¹
HALICIONIDAE		
<i>Gellius</i> sp.	confused mass to isodictyal	(de Laubenfels, 1932) ¹
<i>Haliclona permollis</i> (Bowerbank)	unispicular isodictyal reticulation	(Wells, 1960; de Laubenfels, 1961)
<i>Haliclona</i> sp.		1
<i>Remera japonica</i> Kadota	unispicular isodictyal reticulation	(de Laubenfels, 1936) ¹
<i>Remera okadae</i> Kadota		1
CALYSPONGIIDAE		
<i>Calyspongia diffusa</i> (Ridley)	heavy fibro-reticulation	(de Laubenfels, 1954)

Table 1 (continued)

	Skeletal description	Skeleton described by
POECILOSCLERIDA		
MYXILLIDAE		
<i>Acarus erithacus</i> de Laubenfels	large tracts without reticulation	(Bakus, 1966)
<i>Myxilla agennes</i> de Laubenfels	vague isodictyal reticulation	(de Laubenfels, 1932)
<i>Myxilla incrustans</i> (Esper)	confused mass to isodictyal reticulation	(Bakus, 1966)
MICROCIONIDAE		
<i>Isociona lithophoenix</i> de Laubenfels	dense isodictyal reticulation	(de Laubenfels, 1932)
<i>Microciona astrasanguines</i> Bowerbank	irregular reticulation	(Simpson, 1968)
<i>Microciona coccinea</i> Bergquist	prominent tracts without reticulation	(Bergquist, 1961)
<i>Microciona haematodes</i> de Laubenfels	isodictyal reticulation	(de Laubenfels, 1957)
<i>Microciona seriata</i> (Grant) ⁴	prominent reticulation	(Simpson, 1968)
PSAMMASCIDAE		
<i>Kaneohea poni</i> de Laubenfels	isodictyal reticulation	(de Laubenfels, 1950)
OPHLITASPONGIIDAE		
<i>Ophlitaspongia pennata</i> (Lambe)	ladder-like tracts without reticulation	(Bakus, 1966)
PLOCAMIIDAE		
<i>Hopllocamia neozelanicum</i>	thinly-incrusting; spiculose	(Morton and Miller, 1968)
<i>Plocamia karykina</i> de Laubenfels	ladder-like tracts without reticulation	(Bakus, 1966)
ADOCHIDAE		
<i>Petrosia dura</i>	densely-packed spicules with stout reticulation	(Dendy, 1924 ¹ ; de Laubenfels, 1951 ¹)
<i>Toxidocia violacea</i> de Laubenfels	isodictyal reticulation	(Bergquist, 1965b; de Laubenfels, 1950)
AMPHILECTIDAE		
<i>Biemma rhadia</i> de Laubenfels	spicules bound into bundles without reticulation	(Bakus, 1966)
MYCALIDAE		
<i>Esperiopsis originalis</i> de Laubenfels	reticulated with bound spicules	(Bakus, 1966)
<i>Mycale adhaerens</i> (Lambe)	massive reticulation with bundled spicules	(Bakus, 1966)
<i>Mycale lingua</i> (Bowerbank)	highly reticulated with bundled spicules	(Bakus, 1966)
<i>Mycale macginitiei</i> de Laubenfels	confused mass of spicules	(de Laubenfels, 1932)
<i>Mycale manauakea</i> de Laubenfels	large tracts without reticulation	(de Laubenfels, 1951)
<i>Mycale psila</i> (de Laubenfels)	highly reticulated with bundled spicules	(Bakus, 1966)
<i>Zygierherpe hyaloderma</i> de Laubenfels	ladder-like reticulations	(Bakus, 1966)
DICTYOCERTIDA		
APTYSILLIDAE		
<i>Aptysilla glacialis</i> (Dybowski)	many fibers without reticulation	(de Laubenfels, 1932)
DYSIDEIDAE		
<i>Dysidea fragilis</i> (Montagu)	irregular reticulation	(Bergquist, 1961; de Laubenfels, 1936)
SPONGIIDAE		
<i>Cacospongia scalaria</i>	soft consistency; skeletal form unclear	(de Laubenfels, 1936 ¹)

¹skeletal characteristics assumed to be similar to other species in same genus or family²synonymous with *L. solida* (de Laubenfels, 1950) and *L. floridana*, changed to above by Burton (1963)³synonymous with *H. caruncula* and *H. sanguinea* (Bergquist, 1970)⁴synonymous to *Ophlitaspongia seriata* (Simpson, 1968)

Table 2

Radular characteristics and caecate nature of known sponge-consuming doris nudibranchs.
(Literature citations coded by number and listed at end of table; r=radula description; c=caecum description;
nd=not described.) See figure 1 for explanation of curvature of teeth.

Dorid	Caecate (C)	Radular characteristics			
	or Acaecate (A)	Radular Mean	Formula Range	Curvature of teeth	Reference
DORIDIDAE					
Kentodoridinae				0.21	
<i>Jorunna tomentosa</i> (Cuvier)	(C)	19(23.0.23)	14-24(20-25.0.20-25)	0.21	r- ¹ , ²⁶ c- ¹⁷
Archidoridinae				0.22	
<i>Archidoris montereyensis</i> (Cooper)	(C)	32(53.0.53)	27-36(42-70.0.42-70)	0.12	r- ² , ¹⁴ , ¹⁶ , ²⁰ c- ⁴
<i>Archidoris pseudoargus</i> ^a (Rapp)	(C)	43(72.0.72)	29-56(37-100.0.37-100)	0.19	r- ¹ , ⁵ , ¹¹ , ²³ c- ⁸
<i>Archidoris stellifera</i> (Vayssi�re)	(C)	30(42.0.42)	30(39-45.0.39-45)	0.23	r- ²² , ²³ c-nd
<i>Archidoris odhneri</i> ^b (MacFarland)	(C)	34(55.0.55)		0.36	r- ¹⁵ c- ⁴
<i>Archidoris flammea</i> (Alder & Hancock)	(C)	25(36.0.36)			r- ¹ c-nd
<i>Archidoris wellingtonensis</i> (Abraham)	(C)	42(61.0.61)	33-48(50-75.0.50-75)		r- ⁶ , ⁷ c- ⁷
<i>Ctenodoris flabellifera</i> (Cheeseman)	(C)	40(50.0.50)			r- ⁶ , ⁷ c-nd
Doridinae				0.23	
<i>Doris verrucosa</i> (Cuvier)	(C)	32(37.0.37)	24-42(25-39.0.25-39)	0.20	r- ¹⁰ , ²² , ²³ c-nd
<i>Doriopsis granulosa</i> Pease	(C)	34(44.0.44)	30-38(40-48.0.40-48)	0.11	r- ²⁹ c- ²⁹
<i>Doriopsis pecten</i> (Collingwood)	(C)	31(35.0.35)	30-32(28-42.0.28-42)	0.21	r- ²⁹ c- ²⁹
<i>Doriopsis viridis</i> Pease	(C)	28(25.0.25)	26-30(24-26.0.24-26)	0.38	r- ²⁹ , ³⁰ c- ²⁹
Chromodoridinae				0.23	
<i>Hypselodoris</i> n.s.#1	(C)	28(21.0.21)		0.00	r- ²⁹ c- ²⁹
<i>Hypselodoris peasei</i> (Bergh)	(C)	27(19.0.19)	26-28(17-20.0.17-20)	0.00	r- ²⁹ c- ²⁹
<i>Hypselodoris kayae</i> Young	(C)	28(21.0.21)		0.13	r- ³⁰ c-nd
<i>Hypselodoris vibrata</i> Pease	(C)	47(33.0.33)	38-56(28-38.0.28-38)	0.25	r- ²⁹ c- ²⁹
<i>Glossodoris macfarlandi</i> ^c (Cockerell)	(C)	62(49.0.49)	62(47-50.0.47-50)	0.18	r- ¹⁵ , ²¹ c-nd
<i>Glossodoris amoena</i> Cheeseman	(C)	79(99.0.99)	69-88(77-120.0.77-120)	0.42	r- ⁷ , ²⁰ c-nd
<i>Glossodoris tricolor</i> (Cantraine)	(C)				r-nd c-nd
<i>Cadlina luteomarginata</i> MacFarland	(C)	96(51.0.51)	90-114(47-58.0.47-58)	0.21	r- ¹⁴ , ¹⁵ , ²¹ c- ⁴
<i>Chromodoris dalli</i> Bergh	(C)	112(28.1.28)	112(27-29.1.27-29)	0.22	r- ² c-nd
<i>Chromodoris lilacina</i> (Gould)	(C)	64(40.0.40)	61-66(41-48.0.41-48)	0.25	r- ²⁹ c- ²⁹

Table 2 [continued]

Dorid	Caecate (C) or Acaecate (A)	Radular characteristics			
		Radular Mean	Formula Range	Curvature of teeth	Reference
<i>Chromodoris californiensis</i> ^d (Bergh)	(C)	88(119.0.119)	82-92(98-132.0.98-132)	0.68	r-2, 21 c-nd
Halgerdinae				0.63	
<i>Halgerda rubra</i> Bergh	(C)	34(53.0.53)		0.63	r-29 c-29
Trippinae				0.13	
<i>Trippa scabriuscula</i> (Pease)	(A)	17(18.0.18)		0.13	r-29 c-nd
Discodoridinae				0.11	
<i>Discodoris heathi</i> MacFarland	(A)	21(40.0.40)	20-22(36-42.0.36-42)	0.00	r-14, 15, 17, 21 c-4
<i>Discodoris fragilis</i> (Alder & Hancock)	(A)	20(29.0.29)	18-22(28-30.0.28-30)	0.22	r-29 c-nd
Aldisinae				0.33	
<i>Austrodoris macmurdensis</i> Odhner	(A)	18(25.0.25)	13-22(19-240.019-24)	0.32	r-20 c-nd
<i>Rostanga pulchra</i> MacFarland	(A)	76(76.0.76)	65-80(39-90.0.39-90)	0.33	r-14, 15, 16, 17, 21 c-19
<i>Rostanga arbutus</i> (Angas)	(A)				
<i>Rostanga rubicunda</i> (Cheeseman)	(A)	69(82.0.82)			r-7 c-nd
<i>Rostanga rufescens</i> ^e Iredale & O'Donoghue	(A)				
<i>Aldisa sanguinea</i> (Cooper)	(A)	67(86.0.86)	60-70(70-100.0.70-100)		r-14, 15, 17, 21 c-nd
Diaululinae				0.60	
<i>Diaulula sandiegensis</i> (Cooper)	(A)	21(29.0.29)	19-23(25-34.0.25-34)	0.37	r-15, 15, 17, 21 c-4
<i>Peltodoris atromaculata</i> Bergh	(A)	20(56.0.56)		0.50	r-22, 23 c-9
<i>Anisodoris nobilis</i> (MacFarland)	(A)	26(58.0.58)	23-27(55-62.0.55-62)	0.94	r-14, 15, 17, 21 c-4
HEXABRANCHIDAE				0.29	
<i>Hexabranchus marginatus</i> (Quoy & Gaimard)	(C)	45(78.0.78)		0.29	r-29 c-29
DENDRODORIDIDAE					
<i>Dendrodoris nigra</i> (Stimpson)	(A)	no radula			c-29
<i>Doriopsilla albopunctata</i> ^f (Cooper)	(A)	no radula			c-nd

¹-Alder & Hancock, 1845²-Bergh, 1879³-Bergh, 1880⁴-Bloom, 1974⁵-Burn, 1968⁶-Eliot, 1877⁷-Eliot, 1907⁸-Forrest, 1953^asynonymous with *A. britannica* and *A. tuberculata*, ²⁷, ²⁸^b(*Austrodoris odhneri*), (²⁴), ⁵^c(*Chromodoris macfarlandi*), ²³^d(*Hypselodoris californiensis*), ²⁴; (*Glossodoris californiensis*), ²¹^e(*Doris coccinea*), (*Rostanga coccinea*), ¹³^f(*Dendronotus fulva*), ²⁶⁹-Fournier, 1969¹⁰-Franz, 1970¹¹-Hancock & Embleton, 1852¹²-Hutton, 1881¹³-Iredale & O'Donoghue, 1923¹⁴-MacFarland, 1905¹⁵-MacFarland, 1966¹⁶-Marcus, 1959¹⁷-Marcus, 1961¹⁸-Millott, 1937¹⁹-Moore, unpublished²⁰-Odhner, 1934²¹-O'Donoghue, 1927²²-Provot-Fol, 1951²³-Provot-Fol, 1954²⁴-Roller, 1970²⁵-Rose, 1971²⁶-Steinberg, 1961²⁷-White, 1938²⁸-Winckworth, 1951²⁹-Young, 1966³⁰-Young, 1967³¹-Young, 1969

	Easy	Gradient of ease of fragmentation of the sponge skeleton	Difficult
<i>Trippa scabriuscula</i>	05		22
<i>Discodoris heathi</i>		05	05 05
<i>Discodoris fragilis</i>			22
<i>Aldisia sanguinea</i>			
<i>Austrodoris macmurdensis</i>		08 08 08	
<i>Rostanga pulchra</i>		09	14
<i>Rostanga arbutus</i>			09 28 32 28
<i>Rostanga rufescens</i>		29	
<i>Rostanga rubicunda</i>		31	03 31
<i>Diaulula sandiegensis</i>	05		
<i>Pelodoris atromaculata</i>			
<i>Anisodoris nobilis</i>	16 16	16	14 30
<i>Dendrodoris nigra</i>	22	16 16	16 05
<i>Doriopsilla albopunctata</i>		16	

1-Abeloos & Abeloos, 1932
2-Anderson, 1971
3-Ayling, 1968
4-Baba (in MacFarland, 1966)
5-Bloom¹
6-Carefoot, 1967
-Cook, 1962
8-Dayton et al., 1970¹
9-de Laubenfels, 1927
10-Doran, 1951 (in Cook, 1966)
11-Fisher, 1937 (McMillian, 1942)
12-Flatley, 1922 (in Cook, 1966)
13-Forrest, 1953
14-Fournier, 1969
15-Garstang, 1889
16-McBeth, 1970
17-Miller, 1961
18-Millott, 1937
19-Morton & Miller, 1968
20-Rose, 1971
21-Thompson, 1964
22-Young, 1966
23-Young, 1967
24-6, 17, 18
25-5, 7
26-6, 13, 17, 20, 21
27-1, 15
28-2, 7, 9, 10
29-12, 14
30-5, 16
31-3, 19
32-2, 9

¹species representing less than 10% of diets omitted

¹species representing less than 10% of diets omitted

13-Follett, 1955
14-Fournier, 1969
20-Rose, 1971
21-Thompson, 1964

6-Carefoot, 1967
7-Cook, 1962

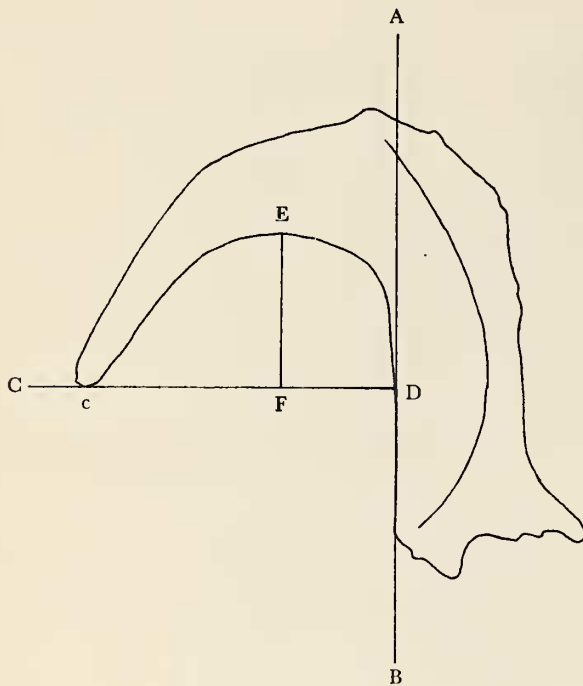


Figure 1

Procedure for estimation of radular tooth curvature

Construct a line (AB) parallel to the shaft; construct a line (CD) perpendicular to AB and touching the tooth tip; construct a line (EF) perpendicular to CD such that the distance between E and F is the maximum possible. The curvature index is:

$$\frac{(\text{distance between E and F})}{(\text{distance between C and D})}$$

per radula for all specimens prepared by the author. Curvature for other species was based on a similar analysis of published tooth drawings.

Preference experiments were done as follows: In the laboratory, food mosaics consisting of pieces (approximately 1 cm³) of *Halichondria panicea* (Pallas, 1766), *Haliclona permollis* (Bowerbank, 1866), *Myxilla incrustans* (Esper, 1805-1814) and *Mycale adhaerens* (Lambe, 1894) (1:1:1:1 by volume) were made available to 3 specimens each of *Archidoris montereyensis*, *A. odhneri* and *Anisodoris nobilis*, and to 2 specimens of *Diaulula sandiegensis*. Each dorid species was presented with its own mosaic to eliminate interspecific behavioral effects. Water entered the experimental chambers centrally at a flow rate of approximately 100 ml/minute. All dorids were starved for 7 days prior to the start of the

experiment (sufficient time for all spicules from previous feedings to be voided from the dorids' digestive tracts). After 5 hours, the dorids were removed from the chambers. They were then cleaned and isolated in clean one-liter capacity plastic containers. Feces were collected, processed and examined as described above. Several random samples were taken from the mosaics and were similarly processed to form a comparison control for density of sponge spicules.

The relative percentage of the characteristic spicule types for each sponge in each fecal sample was estimated. Similarly, the percentage of each spicule type in the controls was estimated. Within the sampling error of the estimation procedure, the amounts of whole sponge available and the amounts of the characteristic spicule types in the controls were identical and exhibited a ratio of 1:1:1:1. The mean percent for each sponge for each dorid species was then calculated.

RESULTS

The taxonomy and skeletal characteristics of sponges known to occur in dorid nudibranch diets are presented in Table 1. Radular characteristics and the presence or absence of a caecum for dorids known to consume sponges are presented in Table 2.

The species of sponges occurring at frequencies of 10% or more in the feces of the dorids mentioned previously, along with an extensive review of dorid-sponge interactions, are presented in Table 3. The taxonomic arrangement of the genera in Table 1 is primarily based on that given by BERGQUIST *et al.* (1971), BERGQUIST & HARTMAN (1969) and BAKUS (1966, personal communication).

The statistical analyses of the distribution of points in Table 3 is given in Table 4. *Diaulula sandiegensis* failed to feed during the course of the preference experiments and therefore will be omitted from further mention. The results of the preference experiments are presented in Table 5.

DISCUSSION

Diets are the result of complex interactions between predator abilities and preferences and prey availability (EMLEN, 1966, 1968; MENGE, 1972; PAINE & VADAS, 1969). There are two underlying assumptions in demonstrating a correlation of predator-to-prey morphologies from diets in nature. The current concept of optimal food selection is that, through the process of evolution acting on the predator, the food that maximizes fitness will become the

preferred prey (EMLEN, 1968). If the supply of food is sufficient and historically stable, specialization is the predicted outcome of natural selection. Furthermore, the specialization is usually reflected in predator morphology (see CODY, 1968). If the supply or stability of the food is low, exploitation of a range of similar foods, *i.e.*, generalization, is predicted. The assumption is then that the most preferred prey will be that prey for which the predator is morphologically adapted.

The second assumption relates to prey availability. If the predator is forced to expand its diet to compensate for scarce resources (MACARTHUR & PIANKA, 1966), diet expansion could act to obscure any correlations of predator-to-prey morphologies. If a correlation of predator-to-prey morphologies can be demonstrated, altering resource availability from the actual (but unknown) quantities to lower levels of availability might destroy the correlation due to generalization of the predator's diet, but an increase in resource availability can only improve the

correlation. The same logic holds with regard to misidentifications of species and erroneous dietary information. These effects would more likely contribute "noise" than information content. Thus a demonstration of the correlation utilizing dietary data from nature would support the hypothesis, while failure to demonstrate the correlation does not necessarily imply negation of the hypothesis, but would cast doubt on the concept of specializations in the sponge-rasping dorid nudibranchs.

The radular anatomy of dorids has been critically examined (YOUNG, 1966, 1969; ROSE, 1971) and the great variance in radula tooth morphology has given rise to the speculation that there might be a correlation to the sponge prey (THOMPSON & BEBBINGTON, 1973). The digestive morphologies of many dorids have been described (HANCOCK & EMBLETON, 1852; BERGH, 1879, 1880; MARCUS, 1961; MORSE, 1968; ROSE, 1971; YOUNG, 1966) and are of 2 types: either the animal possesses a caccum, a spicule-compacting organ of the stomach (MILLOTT, 1937; FOR-

Table 4

Statistical analyses of point distributions in Table 3 (null hypothesis is randomness).
The axes in Table 4 were divided as indicated and the number of symbols per cell were totaled.

Sponge skeletons	Species	Caecate dorids	Acaecate dorids	Chi-Square	Degrees of freedom	Probability
non-reticulated	<i>Leucetta solida</i>					
	to	32	19			
	<i>Myxilla incrustans</i>			5.66	1	<0.025
reticulated	<i>Desmacidon</i> sp.					
	to	6	15			
	<i>Mycale adhaerens</i>					
non-reticulated	<i>Leucetta solida</i>					
	to	22	8			
	<i>Higginsia</i> sp.					
bundled	<i>Rossella racovitzae</i>					
	to	10	11			
	<i>Myxilla incrustans</i>					
isodictyal	<i>Desmacidon</i> sp.					
	to	6	4	17.81	4	<0.001
	<i>Isochiona lithophoenix</i>					
ladder-like	<i>Ophitaspongia pennata</i>					
	to	0	4			
	<i>Plocamia karykina</i>					
reticulated	<i>Zygerherpe hyaloderma</i>					
	to	0	7			
	<i>Mycale adhaerens</i>					